Introduction

Chapter Background

Science & Engineering Indicators 2000 showed that advances in information technology (IT) (i.e., computers and communications products and services) drove an increase in technology development and allowed the United States to increase technical exchanges with its trading partners.[1] This edition of *Science and Engineering Indicators* examines many of the same indicators, with additional perspectives provided by international data on service industries and on patenting activity in two new areas, human DNA sequencing and Internet business methods. New data on applications for U.S. patents by residence of inventor have also been added.[2]

Chapter Organization

This chapter begins with a review of industries that rely heavily on research and development (R&D), referred to here as "high-technology industries."[3] High-technology industries are noted for their high R&D spending and performance, which produce innovations that can be applied to other economic sectors. These industries also help train new scientists, engineers, and other technical personnel (see Nadiri 1993; Tyson 1992). Thus, the market competitiveness of a nation's technological advances, as embodied in new products and processes associated with high-technology industries, can serve as an indicator of the economic and technical effectiveness of that country's science and technology (S&T) enterprise.

The global competitiveness of the U.S. high-technology industry is assessed through an examination of domestic and worldwide market share trends. Data on royalties and fees generated from U.S. imports and exports of technological know-how are used to gauge U.S. competitiveness when technological know-how is sold or rented as intangible (intellectual) property. Also presented are new leading indicators designed to identify those developing and transitioning countries with the potential to become more important exporters of high-technology products over the next 15 years.

This chapter explores several other leading indicators of technology development by examining changing emphases in industrial R&D among the major industrialized countries and comparing U.S. patenting patterns with those of other nations in two important technology areas, human DNA sequencing and Internet business models.

The chapter also examines venture capital disbursements in the United States by stage of financing and by technology area. Venture capital is used in the formation and expansion of small high-technology companies.

U.S. Technology in the Marketplace

Most countries acknowledge a symbiotic relationship between investment in S&T and success in the marketplace: S&T support competitiveness in international trade, and commercial success in the global marketplace provides the resources needed to support new S&T. Consequently, the nation's economic health is a performance measure for the national investment in R&D and in science and engineering (S&E).

The Organisation for Economic Co-operation and Development (OECD) currently identifies four industries as *high-technology* (science-based industries whose products involve above-average levels of R&D): aerospace, computers and office machinery, communications equipment, and pharmaceuticals.[4]

High-technology industries are important to nations for several reasons:

- ♦ High-technology firms innovate, and firms that innovate tend to gain market share, create new product markets, and/or use resources more productively (National Research Council, Hamburg Institute for Economic Research, and Kiel Institute for World Economics 1996; Tassey 1995).
- ♦ High-technology firms develop high value-added products and are successful in foreign markets, which results in greater compensation for their employees (Tyson 1992).
- ♦ Industrial R&D performed by high-technology industries benefits other commercial sectors by generating new products and processes that increase productivity, expand business, and create high-wage jobs (Nadiri 1993; Tyson 1992; Mansfield 1991).

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[1]This chapter presents data from various public and private sources. Consequently, country coverage will vary by data source. Trend data for the advanced industrialized countries are discussed in all sections of the chapter. When available, more limited data for fast-growing and smaller economies are added to the discussion.

[2]Trends in the number and origin of U.S. patent applications provide a more current, albeit less exact, indication of inventive patterns than that provided by the chapter's examination of U.S. patents granted.

[3]No single preferred methodology exists for identifying high-technology industries, but most calculations rely on a comparison of R&D intensities. R&D intensity, in turn, is typically determined by comparing industry R&D expenditures or the numbers of technical people employed (e.g., scientists, engineers, technicians) with industry value added or the total value of its shipments. In this chapter, high-technology industries are identified using R&D intensities calculated by the Organisation for Economic Co-operation and Development.

[4]In designating these high-technology industries, OECD took into account both direct and indirect R&D intensities for 10 countries: the United States, Japan, Germany, France, the United Kingdom, Canada, Italy, the Netherlands, Denmark, and Australia. Direct intensities were calculated by the ratio of R&D expenditure to output (production) in 22 industrial sectors. Each sector was given a weight according to its share in the total output of the 10 countries using purchasing power parities as exchange rates. Indirect intensity calculations were made using technical coefficients of industries on the basis of input-output matrices. OECD then assumed that, for a given type of input and for all groups of products, the proportions of R&D expenditure embodied in value added remained constant. The input-output coefficients were then multiplied by the direct R&D intensities. For further details concerning the methodology used, see OECD (1993).

The Importance of High-Technology Industries

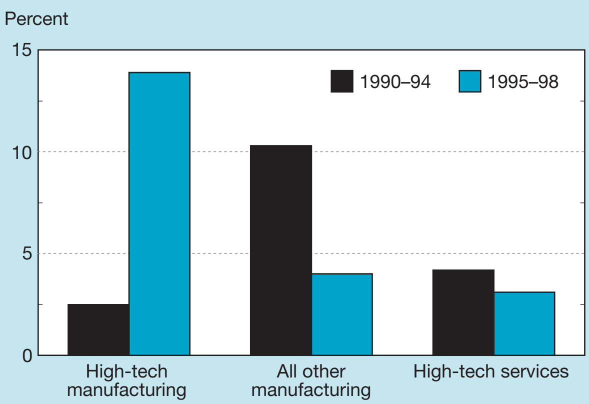
The global market for high-technology goods is growing at a faster rate than that for other manufactured goods, and high-technology industries are driving economic growth around the world.[5] During the 19-year period examined (1980–98), high-technology production grew at an inflation-adjusted average annual rate of nearly 6.0 percent compared with 2.7 percent for other manufactured goods.[6] Global economic activity was especially strong at the end of the period (1995–98), when high-technology industry output grew at 13.9 percent per year, more than three times the rate of growth for all other manufacturing industries. (See figure 6-1 and appendix table 6-1.) Output by the four high-technology industries, those identified as being the most research intensive, represented 7.6 percent of global production of all manufactured goods in 1980; by 1998, this figure rose to 12.7 percent.

During the 1980s, the United States and other high-wage countries devoted increasing resources toward the manufacture of higher value, technology-intensive goods, often referred to as "high-technology manufactures." During this period, Japan led the major industrialized countries in its concentration on high-technology manufactures. In 1980, high-technology manufactures accounted for about 8 percent of total Japanese production, approaching 11 percent in 1984 and increasing to 11.6 percent in 1989. By contrast, high-technology manufactures represented nearly 11 percent of total U.S. production in 1989, up from 9.6 percent in 1980. European nations also saw high-technology manufactures account for a growing share of their total production, although to a lesser degree than seen in the United States and Japan. The one exception was the United Kingdom, where high-technology manufactures rose from 9 percent of total manufacturing output in 1980 to nearly 11 percent by 1989.

[5]This section is based on data reported by WEFA (2000) in its World Industry Service database. This database provides production data for 68 countries and accounts for more than 97 percent of global economic activity.

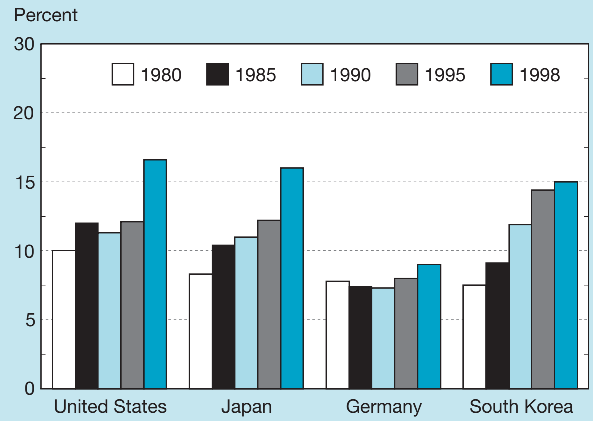
[6]Service-sector industries grew at an inflation-adjusted average annual rate of 3.5 percent during this period.

Figure 6-1.
Global industry sales, average growth rate, by sector



See appendix table 6-1. *Science & Engineering Indicators – 2002*

Figure 6-2.
High-tech industries' share of total manufacturing output



See appendix table 6-1. *Science & Engineering Indicators – 2002*

The major industrialized countries continued to emphasize high-technology manufactures into the 1990s. (See figure 6-2.) In 1998, high-technology manufactures were estimated at 16.6 percent of manufacturing output in the United States, 16.0 percent in Japan, 14.9 percent in the United Kingdom, 11.0 percent in France, and 9.0 percent in Germany.

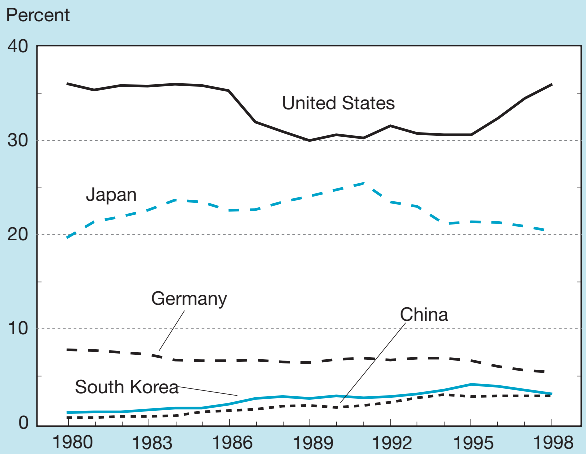
Taiwan and South Korea typify how important R&D-intensive industries have become to newly industrialized economies. In 1980, high-technology manufactures accounted for less than 12 percent of Taiwan's total manufacturing output; this proportion jumped to 16.7 percent in 1989 and reached 25.6 percent in 1998. In 1998, high-technology manufacturing in South Korea (15.0 percent) accounted for about the same percentage of total output as in the United Kingdom (14.9 percent) and almost twice the percentage of total manufacturing output as in Germany (9.0 percent).

Share of World Markets

Throughout the 1980s, the United States was the world's leading producer of high-technology products, responsible for more than one-third of total world production from 1980 to 1987 and for about 30 percent from 1988 to 1995. U.S. world market share began to rise in 1996 and continued moving upward during the following two years. (See figure 6-3.) In 1998, the United States high-technology industry accounted for 36 percent of world high-technology production, a level last reached in the 1980s.

Although the United States struggled to maintain its high-technology market share during the 1980s, Asia's market share followed a path of steady gains. In 1989, Japan accounted for 24 percent of the world's production of high-technology products, moving up 4 percentage points from its 1980 share. Japan continued to gain market share through 1991. Since then,

Figure 6-3.
Country share of global high-tech market: 1980–98



See appendix table 6-1. *Science & Engineering Indicators – 2002*

however, Japan's market share has dropped steadily, falling to 20 percent of world production in 1998 after accounting for nearly 26 percent in 1991.

European nations' share of world high-technology production is much lower and has been declining. Germany's share of world high-technology production was about 8 percent in 1980, about 6.4 percent in 1989, and 5.4 percent in 1998. The United Kingdom's high-technology industry produced 6.7 percent of world output in 1980, dropping to about 6.0 percent in 1989 and 5.4 percent in 1998. In 1980, French high-technology industry produced 6.1 percent of world output; it dropped to 5.3 percent in 1989 and 3.9 percent in 1998. Italy's shares were the lowest among the four large European economies, ranging from a high of about 2.7 percent of world high-technology production in 1980 to a low of about 1.6 percent in 1998.

Developing Asian nations made the most dramatic gains since 1980. South Korea's market share more than doubled during the 1980s, moving from 1.1 percent in 1980 to 2.6 percent in 1989. South Korea's share continued to increase during the early to mid-1990s, peaking at 4.1 percent in 1995. Since 1995, South Korea's market share has dropped each year, falling to 3.1 percent in 1998. Taiwan's high-technology industry also gained world market share during the 1980s and early 1990s before leveling off in the later 1990s. Taiwan's high-technology industry produced just 1.3 percent of the world's output in 1980. This figure rose to 2.4 percent in 1989 and leveled off at 3.3 percent in 1997 and 1998.

Global Competitiveness of Individual Industries

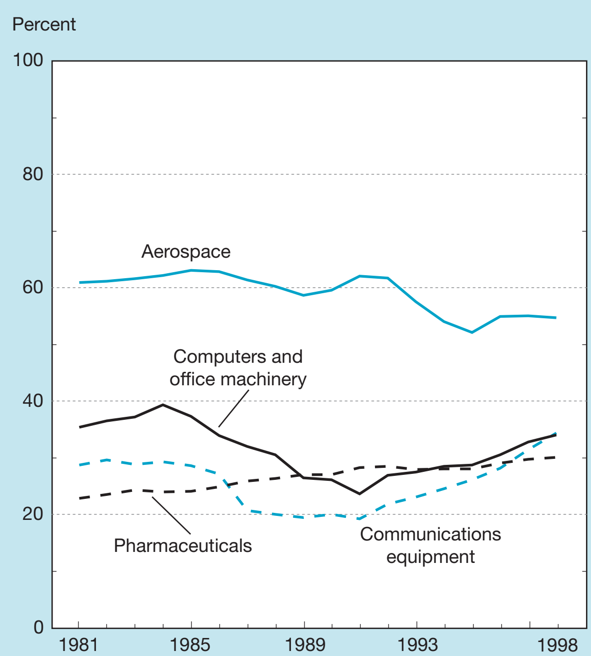
In each of the four industries that make up the high-technology group, the United States maintained strong, if not leading, market positions between 1981 and 1998. Competitive pressures from a growing cadre of high-technology-producing nations contributed to a decline in global market share for two U.S. high-technology industries during the 1980s: computers and office machinery and communications equipment. Both of these U.S. industries reversed their downward trends and gained market share in the mid- to late 1990s, thanks to increased capital investment by U.S. businesses.[7] (See figure 6-4.)

For most of the 19-year period examined, Japan was the world's leading supplier of communications equipment, representing about one-third of total world output. Japan's production surpassed that of the United States in 1981 and held the top position for the next 14 years. In 1995, U.S. manufacturers once again became the leading producer of communications equipment in the world, and they have retained that position ever since. In 1998, the latest year for which data are available, the United States accounted for 34.4 percent of world production of communications equipment, up from 31.5 percent in 1997.

Aerospace, the U.S. high-technology industry with the largest world market share, was the only industry to lose market share in both the 1980s and the 1990s. For most of the 1980s, the U.S. aerospace industry supplied more than 60 percent of world demand. By the late 1980s, the U.S. share of the world aerospace market began an erratic decline, falling to 58.9 percent in 1989 and 52.1 percent by 1995. The United States recovered somewhat during the following three years, supplying about 55 percent of the world market from 1996 to 1998. European aerospace industries, particularly the British

[7]These data are discussed in chapter 8.

Figure 6-4.
U.S. global market share, by high-tech industry: 1981–98



See appendix table 6-1. *Science & Engineering Indicators – 2002*

aerospace industry, made some gains during the period examined. After fluctuating between 8.5 and 10.5 percent during the 1980s, the United Kingdom's industry slowly gained market share for much of the 1990s. In 1991, the United Kingdom supplied 9.7 percent of world aircraft shipments; by 1998, its share had increased to 13 percent.

Of the four U.S. high-technology industries, only the aerospace and pharmaceutical industries managed to retain their number-one rankings throughout the 19-year period; of these two, only the pharmaceutical industry had a larger share of the global market in 1998 than in 1980.

The United States is considered a large, open market. These characteristics benefit U.S. high-technology producers in two important ways. First, supplying a market with many domestic consumers provides scale effects to U.S. producers in the form of potentially large rewards for the production of new ideas and innovations (Romer 1996). Second, the openness of the U.S. market to competing foreign-made technologies pressures U.S. producers to be inventive and more innovative to maintain domestic market share.

Exports by High-Technology Industries

Although U.S. producers benefit from having the world's largest home market as measured by gross domestic product (GDP), mounting trade deficits highlight the need to serve foreign markets as well. U.S. high-technology industries have traditionally been more successful exporters than other U.S. industries and play a key role in returning the United States to a more balanced trade position.

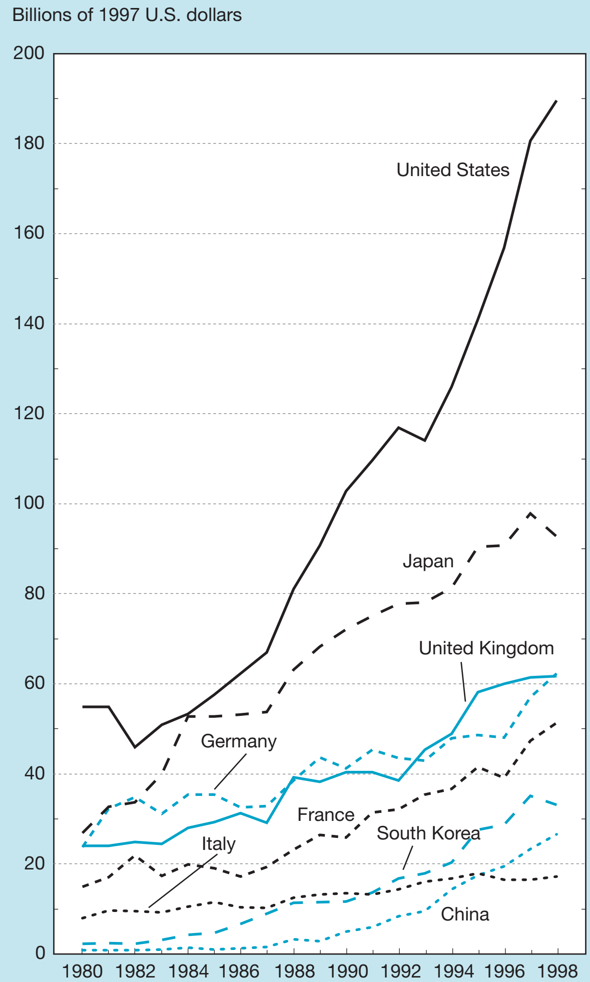
Foreign Markets

Despite its domestic focus, the United States was an important supplier of manufactured products to foreign markets throughout the 1980–98 period. From 1993 to 1998, the United States was the leading exporter of manufactured goods, accounting for about 13 percent of world exports.

U.S. high-technology industries contributed to the strong export performance of the nation's manufacturing industries. (See figure 6-5 and appendix table 6-1.) During the same 19-year period, U.S. high-technology industries accounted for between 19 and 26 percent of world high-technology exports, which was at times twice the level achieved by all U.S. manufacturing industries. In 1998, the latest year for which data are available, exports by U.S. high-technology industries accounted for 19.8 percent of world high-technology exports; Japan was second with 9.7 percent, followed by Germany with 6.5 percent.

The gradual drop in U.S. share during the 19-year period was in part the result of emerging high-technology industries in newly industrialized economies, especially in Asia. In 1980, high-technology industries in Singapore and Taiwan each accounted for about 2.0 percent of world high-technology exports. The latest data for 1998 show Singapore's share reaching 6.4 percent and Taiwan's share reaching 5.0 percent.

Figure 6-5.
High-tech exports: 1980–98



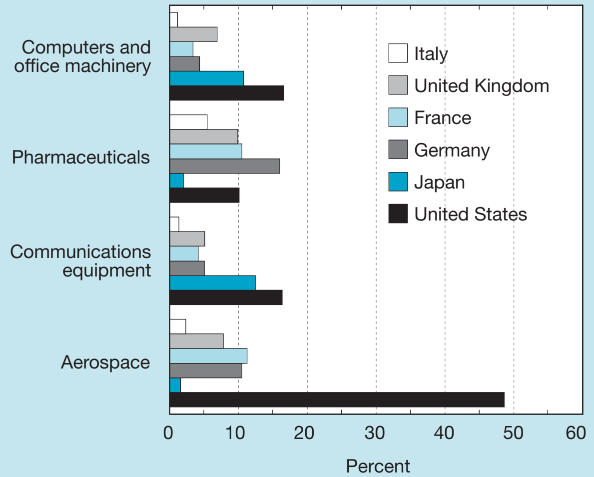
See appendix table 6-1. *Science & Engineering Indicators – 2002*

Industry Comparisons

Throughout the 19-year period, individual U.S. high-technology industries ranked either first or second in exports in each of the four industries that make up the high-technology group. In 1998, the United States was the export leader in three industries and second in only one, pharmaceuticals. (See figure 6-6.)

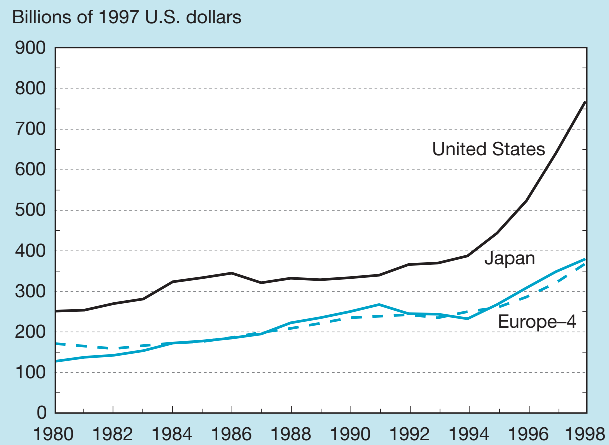
U.S. industries producing aerospace technologies, computers and office machinery, and pharmaceuticals all accounted for smaller shares of world exports in 1998 than in 1980; only the communications equipment industry improved its share during the period. By contrast, Japan's share of world exports of communications equipment dropped steadily after 1985, eventually falling to 12.5 percent by 1998 from a high of 36.0 percent just 13 years earlier. Several smaller Asian nations fared better: for example, in 1998, South Korea supplied 5.9 percent of world communication product exports, up from just 2.4 percent in 1980, and Singapore supplied 10.6 percent of world office and computer exports in 1998, up from 0.6 percent in 1980.

Figure 6-6.
Export market share in high-tech industries: 1998



See appendix table 6-1. *Science & Engineering Indicators – 2002*

Figure 6-7.
National apparent consumption[1] of high-tech products: 1980–98



[1]Apparent consumption equals gross output plus imports minus exports corrected for implied service costs associated with export sales.

NOTE: Europe–4 refers to the four largest European economies: Germany, France, the United Kingdom, and Italy.

See appendix table 6-1. *Science & Engineering Indicators – 2002*

Competition in the Home Market

A country's home market is often considered the natural destination for the goods and services domestic firms have produced. Proximity to the customer as well as common language, customs, and currency make marketing at home easier than marketing abroad.

With trade barriers falling, however, product origin may be only one factor among many influencing consumer choice. As the number of firms producing goods to world standards rises, price, quality, and product performance often become equally or more important criteria for selecting products. Thus, in the absence of trade barriers, the intensity of competition faced by producers in the domestic market can approach and, in some markets, exceed that faced in foreign markets. U.S. competitiveness in foreign markets may be the result of two factors: the existence of tremendous domestic demand for the latest technology products and the pressure of global competition, which spurs innovation.

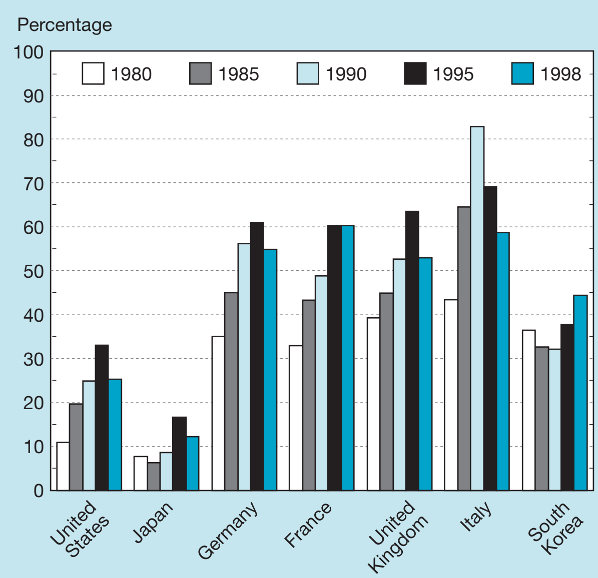
National Demand for High-Technology Products

Demand for high-technology products in the United States far exceeds that in any other single country; in 1998, it was larger (approximately $768 billion) than the combined markets of Japan and the four largest European nations—Germany, the United Kingdom, France, and Italy (about $749 billion). (See figure 6-7.) In 1991, Japan was the world's second largest market for high-technology products, although its percentage share of world consumption has generally declined since then. Even though economic problems across much of Asia have curtailed a long period of rapid growth, Asia continues to be a large market for the world's high-technology exports.

National Producers Supplying the Home Market

Throughout the 1980–95 period, the world's largest market for high-technology products, the United States, was served primarily by domestic producers, yet demand was increasingly met by a growing number of foreign suppliers. (See figure 6-8.) In 1998, U.S. producers supplied about 75 percent of the home market for high-technology products; in 1995, their share was much lower—about 67 percent.

Figure 6-8.
Import share of domestic high-tech markets



See appendix table 6-1. *Science & Engineering Indicators – 2002*

Other countries, particularly those in Europe, have experienced increased foreign competition in their domestic markets. A more economically unified market has made Europe especially attractive to the rest of the world. Rapidly rising import penetration ratios in Germany, the United Kingdom, France, and Italy during the latter part of the 1980s and throughout much of the 1990s reflect these changing circumstances. These data also highlight greater trade activity in European high-technology markets compared with product markets for less technology-intensive manufactures.

The Japanese home market, the second largest market for high-technology products and historically the most self-reliant of the major industrialized countries, also increased its purchases of foreign technologies over the 19-year period, although slowly. In 1998, imports of high-technology manufactures supplied about 12 percent of Japanese domestic consumption, up from about 7 percent in 1980.

Global Business in Knowledge-Intensive Service Industries

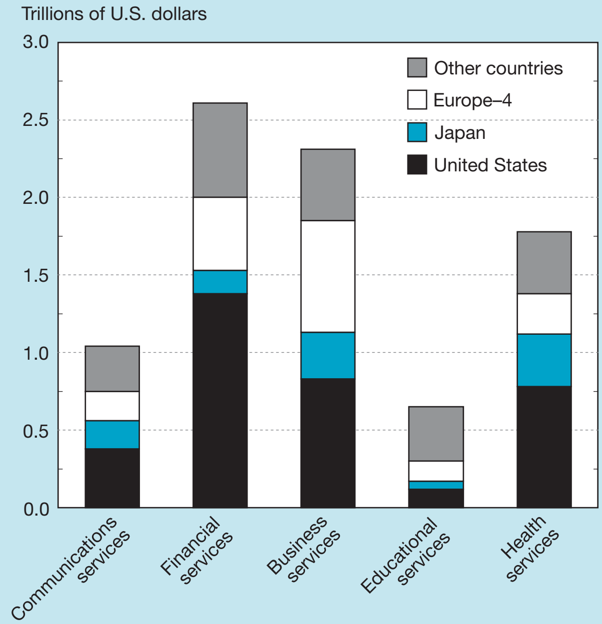
For several decades, revenues generated by U.S. service-sector industries have grown faster than those generated by the nation's manufacturing industries. Data collected by the Department of Commerce show that the service sector's share of the U.S. GDP grew from 49 percent in 1959 to 64 percent in 1997 (National Science Board 2000; appendix table 9-4). Service-sector growth has been fueled largely by "knowledge-intensive" industries—those incorporating science, engineering, and technology in their services or in the delivery of those services. Five of these knowledge-intensive industries are communications services, financial services, business services (including computer software development), educational services, and health services. These industries have been growing faster than the high-technology manufacturing sector discussed earlier. This section presents data tracking overall revenues earned by these industries in 68 countries.[8] (See figure 6-9 and appendix table 6-2.)

Combined sales in 1997 dollars in these five service-sector industries approached $8.4 trillion in 1998, up from $6.8 trillion in 1990 and $4.8 trillion in 1980. The United States was the leading provider of high-technology services, responsible for between 38 and 41 percent of total world service revenues during the entire 19-year period examined.

The financial services industry is the largest of the five service industries examined, accounting for 31 percent of revenues in 1998. The U.S. financial services industry is the world's largest, with 52.9 percent of world revenues in 1998. Japan was second at 5.9 percent, followed by Germany at 4.1 percent.

Business services, which includes computer and data processing and research and engineering services, is the second largest service sector, accounting for nearly 28 percent of revenues in 1998. The U.S. business services industry is the largest in the world, with 36.0 percent of industry revenues in

Figure 6-9.
Global revenues generated by five knowledge-intensive service industries: 1998



NOTE: Europe–4 refers to the four largest European economies: Germany, France, the United Kingdom, and Italy.

See appendix table 6-2. *Science & Engineering Indicators – 2002*

1998. France is second with 17.1 percent, followed by Japan with 12.9 percent and the United Kingdom with 6.1 percent. Unfortunately, data on individual business services by country are not available.

Communications services, which includes telecommunications and broadcast services, is the fourth-largest service industry examined, accounting for 12.3 percent of revenues in 1998. In what many consider the most technology-driven of the service industries, the United States has the dominant position. In 1998, U.S. communications firms generated revenues that accounted for 36.8 percent of world revenues, more than twice the share held by Japanese firms and six times that held by British firms.

Because in many nations the government is the primary provider of the remaining two knowledge-intensive service industries (health services and educational services), and because the size of a country's population affects the delivery of these services, global comparisons are more difficult and less meaningful than those for other service industries. The United States, with the largest population and least government involvement, has the largest commercial industries in the world in both health services and educational services. Japan is second, followed by Germany. Educational services, the smallest of the five knowledge-intensive service industries, had about one-fourth of the revenues generated by the financial services industry worldwide.

[8]Unlike those for manufacturing industries, national data that track activity in many of the hot new service sectors are limited in the level of industry disaggregation available and the types of activity for which national data are collected.

U.S. Trade Balance in Technology Products

Although no single preferred methodology exists for identifying high-technology industries, most calculations rely on a comparison of R&D intensities. R&D intensity, in turn, is typically determined by comparing industry R&D expenditures or the number of technical people employed (e.g., scientists, engineers, and technicians) with industry value added or the total value of its shipments.[9] Classification systems based on R&D intensity, however, are often distorted by including all products produced by particular high-technology industries, regardless of the level of technology embodied in each product, and by the somewhat subjective process of assigning products to specific industries. In contrast, the classification system discussed here allows for a highly disaggregated, more focused examination of technology embodied in traded goods. To minimize the impact of subjective classification, the judgments offered by government experts are reviewed by other experts.

The Bureau of the Census has developed a classification system for exports and imports that embody new or leading-edge technologies. This classification system allows trade to be examined in 10 major technology areas:

- **Biotechnology—**the medical and industrial application of advanced genetic research to the creation of drugs, hormones, and other therapeutic items for both agricultural and human uses.
- **Life science technologies—**the application of nonbiological scientific advances to medicine. For example, advances such as nuclear magnetic resonance imaging, echocardiography, and novel chemistry, coupled with new drug manufacturing, have led to new products that help control or eradicate disease.
- **Opto-electronics—**the development of electronics and electronic components that emit or detect light, including optical scanners, optical disk players, solar cells, photosensitive semiconductors, and laser printers.
- **Information and communications—**the development of products that process increasing amounts of information in shorter periods of time, including fax machines, telephone switching apparatus, radar apparatus, communications satellites, central processing units, and peripheral units such as disk drives, control units, modems, and computer software.
- **Electronics—**the development of electronic components (other than opto-electronic components), including integrated circuits, multilayer printed circuit boards, and surface-mounted components, such as capacitors and resistors, that result in improved performance and capacity and, in many cases, reduced size.
- **Flexible manufacturing—**the development of products for industrial automation, including robots, numerically controlled machine tools, and automated guided vehicles, that permit greater flexibility in the manufacturing process and reduce human intervention.
- **Advanced materials—**the development of materials, including semiconductor materials, optical fiber cable, and videodisks, that enhance the application of other advanced technologies.
- **Aerospace—**the development of aircraft technologies, such as most new military and civil airplanes, helicopters, spacecraft (with the exception of communication satellites), turbojet aircraft engines, flight simulators, and automatic pilots.
- **Weapons—**the development of technologies with military applications, including guided missiles, bombs, torpedoes, mines, missile and rocket launchers, and some firearms.
- **Nuclear technology—**the development of nuclear production apparatus, including nuclear reactors and parts, isotopic separation equipment, and fuel cartridges (nuclear medical apparatus is included in life sciences rather than this category).

To be included in a category, a product must contain a significant amount of one of the leading-edge technologies, and the technology must account for a significant portion of the product's value.

Importance of Advanced Technology Product Trade to Overall U.S. Trade

Advanced technology products accounted for an increasing share of all U.S. trade (exports plus imports) in merchandise between 1990 and 1999. (See text table 6-1 and appendix table 6-3.) Total U.S. trade in merchandise exceeded $1.7 trillion in 1999; of that, $381 billion involved trade in advanced technology products. Trade in advanced technology products accounts for a much larger share of U.S. exports than of imports (29.2 percent versus 17.5 percent in 1999) and makes a positive contribution to the overall balance of trade. After several years in which the surplus generated by trade in advanced technology products declined, exports of U.S. advanced technology products outpaced imports in 1996 and 1997, producing larger surpluses in both years. In 1998 and 1999, the economic slowdown in Asia caused declines in exports and in the surplus generated from U.S. trade in advanced technology products.

Technologies Generating Trade Surpluses

Throughout the 1990s, U.S. exports of advanced technology products exceeded imports in 8 of 11 technology areas.[10] Trade in aerospace technologies consistently produced the largest surpluses for the United States. Those surpluses narrowed in the mid-1990s as competition from Europe's aerospace industry challenged U.S. companies' preeminence both

[9] See footnote 2 for a discussion of the methodology.

[10] Software products is not a separate advanced technology products category; it is included in the category covering information and communications products. To better examine this important technology area, software products was broken out from the information and communications, creating an 11th category.

Text table 6-1.
U.S. international trade in merchandise

Type of trade	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Total trade (billions of U.S.$)	888.3	910.0	979.9	1,045.3	1,176.2	1,325.3	1,410.8	1,556.1	1,587.5	1,714.3
Technology products (%)	17.3	18.1	18.3	18.1	18.6	19.9	20.2	21.0	21.6	22.2
Other merchandise (%)	82.7	81.9	81.7	81.9	81.4	80.1	79.8	79.0	78.4	77.8
Total exports (billions of U.S.$)	393.0	421.9	447.5	464.8	512.4	575.9	611.5	679.7	670.3	684.4
Technology products (%)	24.1	24.1	23.9	23.3	23.6	24.0	25.3	26.4	27.8	29.2
Other merchandise (%)	75.9	75.9	76.1	76.7	76.4	76.0	74.7	73.6	72.2	70.8
Total imports (billions of U.S.$)	495.3	488.1	532.4	580.5	663.8	749.4	799.3	876.4	917.2	1,029.9
Technology products (%)	12.0	13.0	13.5	14.0	14.8	16.7	16.3	16.8	17.1	17.5
Other merchandise (%)	88.0	87.0	86.5	86.0	85.2	83.3	83.7	83.2	82.9	82.5

NOTE: Total trade is the sum of total exports and total imports.

SOURCE: U.S. Bureau of the Census, Foreign Trade Division (2001). Available at <http://www.fedstats.gov>, March 2001.

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at home and in foreign markets. Aerospace technologies generated a net inflow of $25 billion in 1990 and nearly $29 billion in 1991 and 1992; trade surpluses then declined 13 percent in 1993, 9 percent in 1994, and 4 percent in 1995. In 1998, U.S. trade in aerospace technologies produced a net inflow of $39 billion, the largest surplus of the decade, and 1999's surplus was only slightly smaller at $37 billion. Trade is more balanced in five other technology areas (biotechnology, flexible manufacturing technologies, advanced materials, weapons, and nuclear technology), with exports having only a slight edge over imports. Each of these areas showed trade surpluses of less than $3 billion in 1999.

Although U.S. imports of electronics technologies exceeded exports for much of the decade, 1997 saw U.S. exports of electronics exceed imports by $1.1 billion, which jumped to $4.2 billion in 1998 and $9.4 billion in 1999. This turnaround may be attributed in part to Asia's economic problems in 1998 and a stronger U.S. dollar, which may have reduced the number of electronics products imported from Asia in 1998. Imports from Asia recovered to pre-1998 levels in 1999, with the largest jumps in imports coming not from Japan but from South Korea, the Philippines, and Malaysia.

Technologies Generating Trade Deficits

In 1999, trade deficits were recorded in three technology areas: information and communications, opto-electronics, and life science technologies. The trends for each of these technology areas are quite different. Only opto-electronics showed trade deficits in each of the 10 years examined. U.S. trade in life science technologies consistently generated annual trade surpluses until 1998. Life science exports were virtually flat in the last two years of the decade, while imports jumped 24 percent in 1998 and 21 percent in 1999. Interestingly, in a technology area in which the United States is considered to be at the forefront (information and communications), annual U.S. imports have consistently exceeded exports since 1992. Nearly three-fourths of all U.S. imports in this technology area are produced in Asia.[11]

[11]The Bureau of the Census is not able to identify the degree to which this trade is between affiliated U.S. and foreign companies.

Top Customers by Technology Area

Japan and Canada are the largest customers for a broad range of U.S. technology products, with each country accounting for about 11 percent of total U.S. technology exports. Japan ranks among the top three customers in 9 of 11 technology areas, Canada in 7. (See figure 6-10 and appendix table 6-4.) European countries are also important consumers of U.S. technology products, particularly Germany (life science products, opto-electronics, and advanced materials), the United Kingdom (aerospace, weapons, and computer software), and the Netherlands (life science products and weapons).

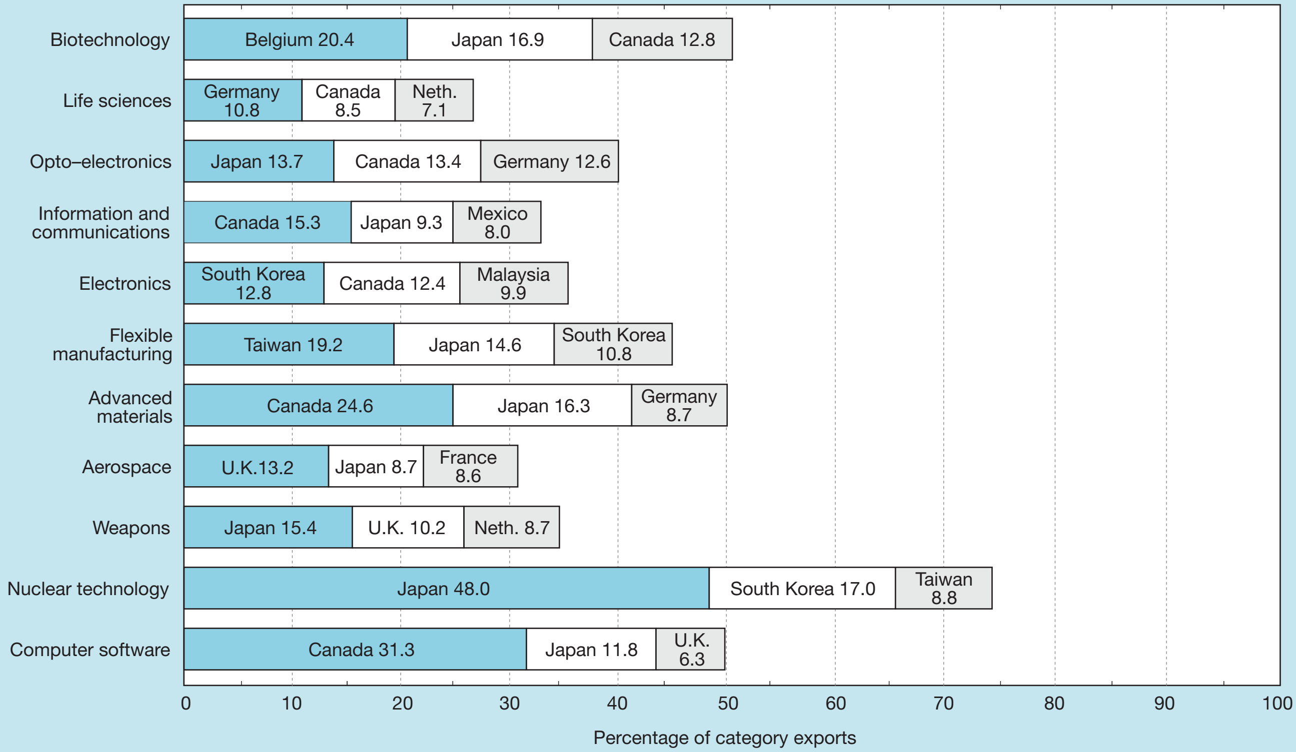
Although Europe, Japan, and Canada have long been important consumers of U.S. technology products, several newly industrialized and emerging Asian economies now also rank among the largest customers. South Korea is a leading consumer in three technology areas (electronics, flexible manufacturing, and nuclear technologies) and Taiwan in two (flexible manufacturing and nuclear technologies).

Top Suppliers by Technology Area

The United States is not only an important exporter of technologies to the world but also a consumer of imported technologies. The leading economies in Asia and Europe are important suppliers to the U.S. market in each of the 11 technology areas. (See figure 6-11 and appendix table 6-5.) Japan is a major supplier in six advanced technology categories; Canada, France, Germany, Taiwan, and the United Kingdom in three. Smaller European countries are also major suppliers of technology to the United States, although they tend to specialize. Belgium was the top foreign supplier of biotechnology products to the United States in 1999, the source for 25.5 percent of imports in this category. Switzerland also was among the top three suppliers of biotechnology products with 11.3 percent.

Many technology products come from developing Asian economies, especially Malaysia, South Korea, and Singapore. Imports from these Asian economies and from other regions into one of the world's most demanding markets indicate that technological capabilities are expanding globally.

Figure 6-10.
Three largest export markets for U.S. technology products: 1999



See appendix table 6-4.

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U.S. Royalties and Fees Generated From Intellectual Property

The United States has traditionally maintained a large trade surplus in intellectual property. Firms trade intellectual property when they license or franchise proprietary technologies, trademarks, and entertainment products to entities in other countries. These transactions generate net revenues in the form of royalties and licensing fees.

U.S. Royalties and Fees From All Transactions

Total U.S. receipts from all trade in intellectual property more than doubled between 1990 and 1999, reaching nearly $36.5 billion in 1999. (See appendix table 6-6.) During the 1987–96 period, U.S. receipts for transactions involving intellectual property were generally four to five times larger than U.S. payments to foreign firms. The gap narrowed in 1997 as U.S. payments increased by 20 percent over the previous year and U.S. receipts rose less than 3 percent. Despite the much larger increase in payments, annual receipts from total U.S. trade in intellectual property in 1997 were still more than 3.5 times greater than payments. This trend continued during the following two years, and by 1999, the ratio of receipts to payments had dropped to about 2.7:1.

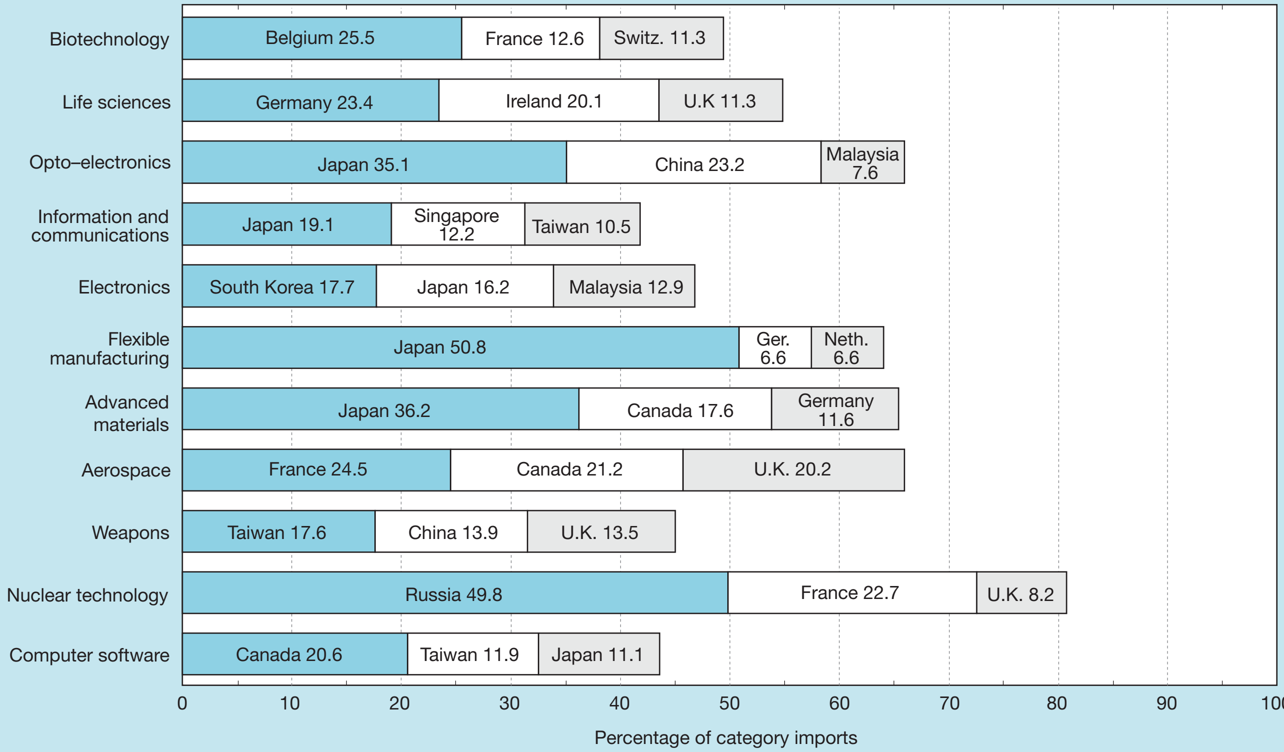
U.S. trade in intellectual property produced a surplus of $23.2 billion in 1999, down slightly from the nearly $24.5 billion surplus recorded a year earlier. (See figure 6-12.) About 75 percent of the transactions involved exchanges of intellectual property between U.S. firms and their foreign affiliates.[12] Exchanges of intellectual property among affiliates have grown at about the same pace as those among unaffiliated firms, except during the late 1990s, when the growth in U.S. firm payments to affiliates exceeded receipts. These trends suggest both a growing internationalization of U.S. business and a growing reliance on intellectual property developed overseas.

U.S. Royalties and Fees From Trade in Technical Knowledge

Data on royalties and fees generated by trade in intellectual property can be further disaggregated to reveal U.S. trade in technical know-how. The following data describe transactions between unaffiliated firms where prices are set through a market-based negotiation. Therefore, they may better reflect the exchange of technical know-how and its market value at a given time than do data on exchanges among affiliated firms. When receipts (sales of technical know-how) consistently exceed payments (purchases), these data may indicate a comparative advantage in the creation of industrial technology. The record of

[12]An *affiliate* refers to a business enterprise located in one country that is directly or indirectly owned or controlled by an entity of another country. The controlling interest for an incorporated business is 10 percent or more of its voting stock; for an unincorporated business, it is an interest equivalent to 10 percent of voting stock.

Figure 6-11.
Top three foreign suppliers of technology products to the United States: 1999



See appendix table 6-5. *Science & Engineering Indicators – 2002*

resulting receipts and payments also provides an indicator of the production and diffusion of technical knowledge.

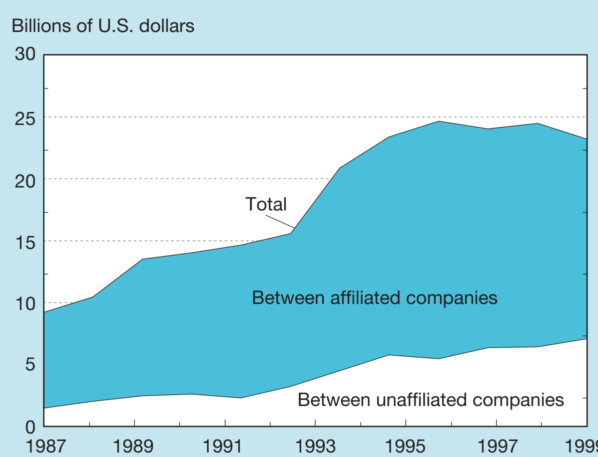
The United States is a net exporter of technology sold as intellectual property, although the gap between imports and exports narrowed during the late 1990s. During the first half of the 1990s, royalties and fees received from foreign firms have been an average of three times the amount U.S. firms pay foreigners to access their technology. Between 1996 and 1998, receipts plateaued at about $3.5 billion. In 1999, receipts totaled nearly $3.6 billion, little changed from the year before but still more than double that reported for 1987. (See figure 6-13 and appendix table 6-7.)

Japan is the world's largest consumer of U.S. technology sold as intellectual property, although its share declined significantly during the 1990s. In 1999, Japan accounted for about 30 percent of all such receipts. At its peak in 1993, Japan's share was 51 percent.

Another Asian country, South Korea, is the second largest consumer of U.S. technology sold as intellectual property, accounting for nearly 14 percent of U.S. receipts in 1999. South Korea has been a major consumer of U.S. technological know-how since 1988, when it accounted for 5.5 percent of U.S. receipts. South Korea's share rose to 10.7 percent in 1990 and reached its highest level, 17.3 percent, in 1995.

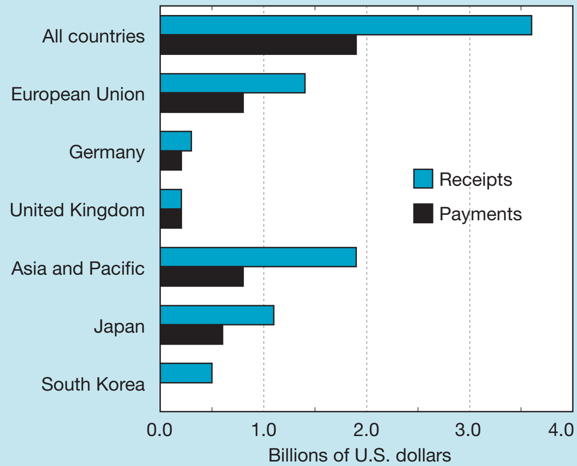
The U.S. trade surplus in intellectual property is driven largely by trade with Asia, but that surplus has narrowed recently. In 1995, U.S. receipts (exports) from technology licensing transactions were nearly seven times the U.S. firm payments (imports) to Asia. That ratio closed to just more than 4:1 by 1997, and the most recent data show U.S. receipts from technology licensing transactions at about 2.5 times the U.S. firm payments to Asia. As previously noted, Japan and South Korea were the biggest customers for U.S. technology sold as intellectual property; together, these countries ac-

Figure 6-12.
U.S. trade balance of royalties and fees: 1987–99



See appendix table 6-6. *Science & Engineering Indicators – 2002*

Figure 6-13.
U.S. royalties and fees generated from the exchange of industrial processes between unaffiliated companies: 1999



See appendix table 6-7. *Science & Engineering Indicators – 2002*

counted for more than 44 percent of total receipts in 1999.

Until 1994, U.S. trade with Europe in intellectual property, unlike trade with Asia, fluctuated between surplus and deficit. In 1994, a sharp decline in U.S. purchases of European technical know-how led to a considerably larger surplus for the United States compared with earlier years. The following year showed another large surplus resulting from a jump in receipts from the larger European countries. In 1999, receipts from European Union (EU) countries represented about 35 percent of U.S. technology sold as intellectual property, more than double the share in 1993. Some of this increase is attributable to increased licensing by firms in Germany, the third largest consumer of U.S. technological know-how. In 1999, Germany's share rose to 9.3 percent, up from 6.9 percent in 1998 and more than double its share in 1993. These latest data show receipts from France and Sweden rising sharply during the late 1990s, causing a considerably larger surplus from U.S. trade with Europe in intellectual property in 1998 and 1999.

U.S. firms have purchased technical know-how from different foreign sources over the years, with increasing amounts coming from Japan, which since 1992 has been the single largest foreign supplier of technical know-how to U.S. firms. About one-third of U.S. payments in 1999 for technology sold as intellectual property were made to Japanese firms. Europe accounts for slightly more than 44 percent of the foreign technical know-how purchased by U.S. firms; the United Kingdom and Germany are the principal European suppliers.[13]

New High-Technology Exporters

Several nations have made tremendous technological leaps forward over the past decade. Some of these countries are well positioned to play more important roles in technology development because of their large and continuing investments in S&E education and R&D.[14] However, their success may hinge on other factors as well, including political stability, access to capital, and an infrastructure that can support technological and economic advancement.

This section assesses a group of selected countries and their potential to become more important exporters of high-technology products during the next 15 years, based on the following leading indicators:

- **National orientation—**evidence that a nation is taking action to become technologically competitive, as indicated by explicit or implicit national strategies involving cooperation between the public and private sectors.
- **Socioeconomic infrastructure—**the social and economic institutions that support and maintain the physical, human, organizational, and economic resources essential to the functioning of a modern, technology-based industrial nation. Indicators include the existence of dynamic capital markets, upward trends in capital formation, rising levels of foreign investment, and national investments in education.
- **Technological infrastructure—**the social and economic institutions that contribute directly to a nation's ability to develop, produce, and market new technology. Indicators include the existence of a system for the protection of intellectual property rights (IPR), the extent to which R&D activities relate to industrial application, competency in high-technology manufacturing, and the capability to produce qualified scientists and engineers.
- **Productive capacity—**the physical and human resources devoted to manufacturing products and the efficiency with which those resources are used. Indicators include the current level of high-technology production, the quality and productivity of the labor force, the presence of skilled labor, and the existence of innovative management practices.

This section analyzes 15 economies: 6 in Asia (China, India, Indonesia, Malaysia, the Philippines, and Thailand); 3 in Central Europe (Czech Republic, Hungary, and Poland); 4 in Latin America (Argentina, Brazil, Mexico, and Venezuela); and 2 others (Ireland and Israel) that have shown increased technological activity.[15]

National Orientation

The national orientation indicator identifies nations whose businesses, government, and culture encourage high-technology development. This indicator was constructed using information from a survey of international experts and published

[13]Over the years, France has also been an important source of technological know-how. In 1996, France was the leading European supplier to U.S. firms. Since then, data on France have been suppressed to avoid disclosing individual company operations.

[14]See chapter 2 for the discussion of international higher education trends and chapter 4 for the discussion of trends in international R&D.

[15]See Porter and Roessner (1991) for details on survey and indicator construction; see Roessner, Porter, and Xu (1992) for information on the validity and reliability testing the indicators have undergone.